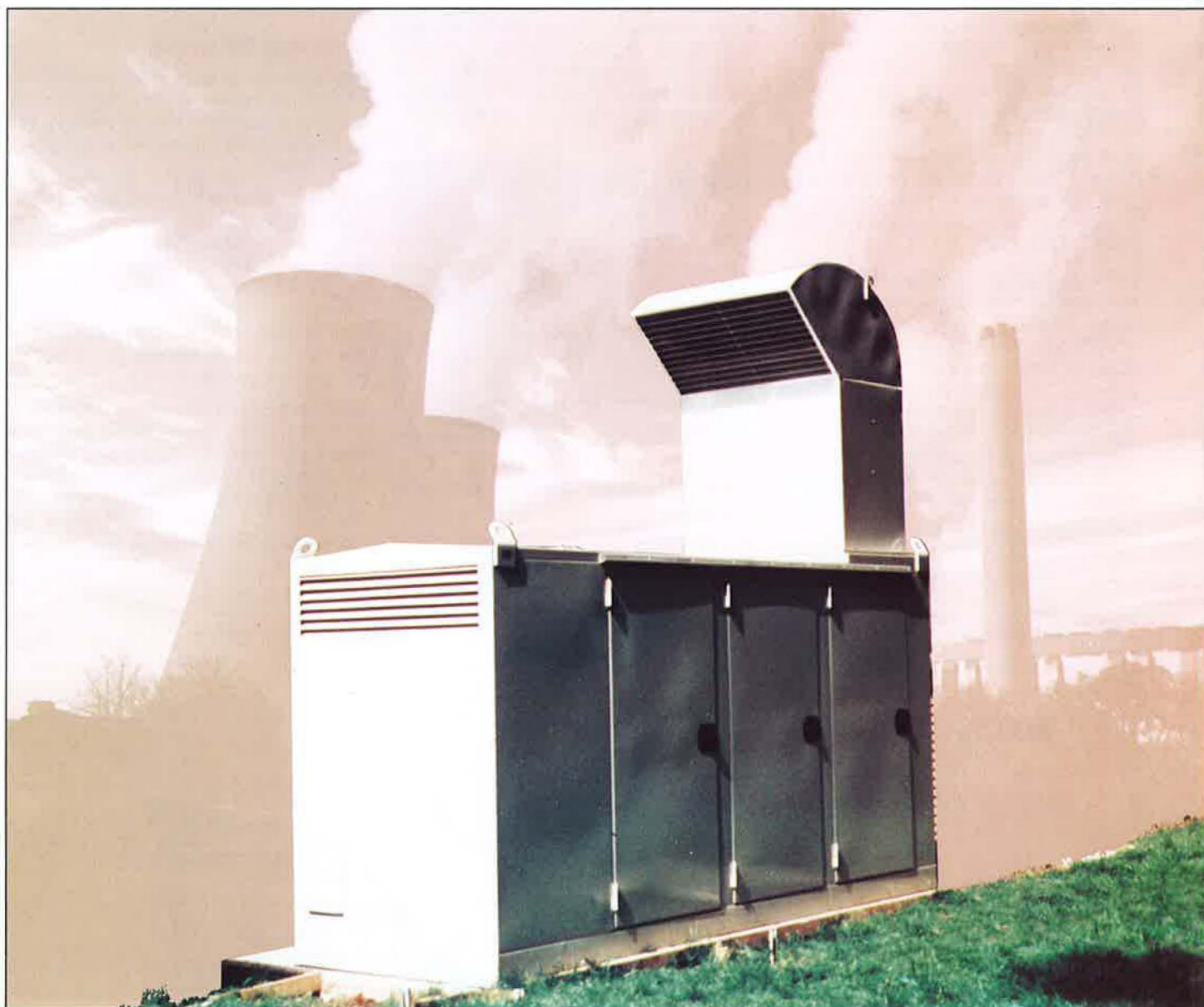


# *Guide 115*

## **An Environmental Guide to Small-Scale Combined Heat and Power**



ENERGY EFFICIENCY

## Combined Heat and Power - the Environment-Friendly Option for Buildings

In recent years there has been a growing concern about the effect that emissions from power stations can have on our environment, particularly in relation to the greenhouse effect and global warming. However, there is much that we as individuals can do to make a significant contribution to reducing these emissions - especially when the individual has responsibility for a building.

The aim of this guide is to explain the environmental benefits and requirements of a cost-effective technology, which provides an alternative power source. The technology is combined heat and power, commonly known as CHP. An introduction to the technology and application of small-scale gas engine CHP is given in Good Practice Guide No 3, and more detailed technical information on the environmental aspects of CHP systems is given in Good Practice Guide No 116.

CHP is suitable for buildings which have a simultaneous need for hot water and electricity. Typical examples include hotels, leisure centres with swimming pools, grouped accommodation, colleges and university campuses and hospitals. This guide focuses on small-scale packaged gas engine CHP. Small-scale generally refers to units with an electrical output of up to 500 kW, although such packaged equipment is available up to about 1 MW.

This guide shows how significant environmental improvements can be achieved by installing gas engine CHP. It considers:

- the damaging effects that exhaust gases have on the environment;

- the degree to which small-scale CHP can reduce exhaust emissions;
- ways of ensuring that CHP has no harmful effects on the locality in which it is installed;
- the latest systems which achieve even greater emission reductions;
- the need to maintain engines to ensure continued energy efficiency and environmental benefits.

Already in the UK there are over 700 gas engine CHP plants in buildings, generating approximately 340 GWh/year - that's equivalent to 39,000 one kilowatt electric fires burning all year long. These units are already making important contributions to the environment. Could CHP be an environment-friendly option for your building?

### The Greenhouse Effect and Global Warming

As carbon dioxide and other gases build up in the atmosphere, more of the sun's heat is trapped - the greenhouse effect. This is likely to result in the earth getting hotter - global warming. This could have an irreversible effect on the planet's climate, increasing the risk of storms, coastal flooding and drought.

### CHP Systems Come Made-to-Measure

For buildings that have a simultaneous need for heat and power, CHP systems are a popular method for providing both electricity and hot water from the same installation, supplementing the use of

boiler plant and electric power from the National Grid.

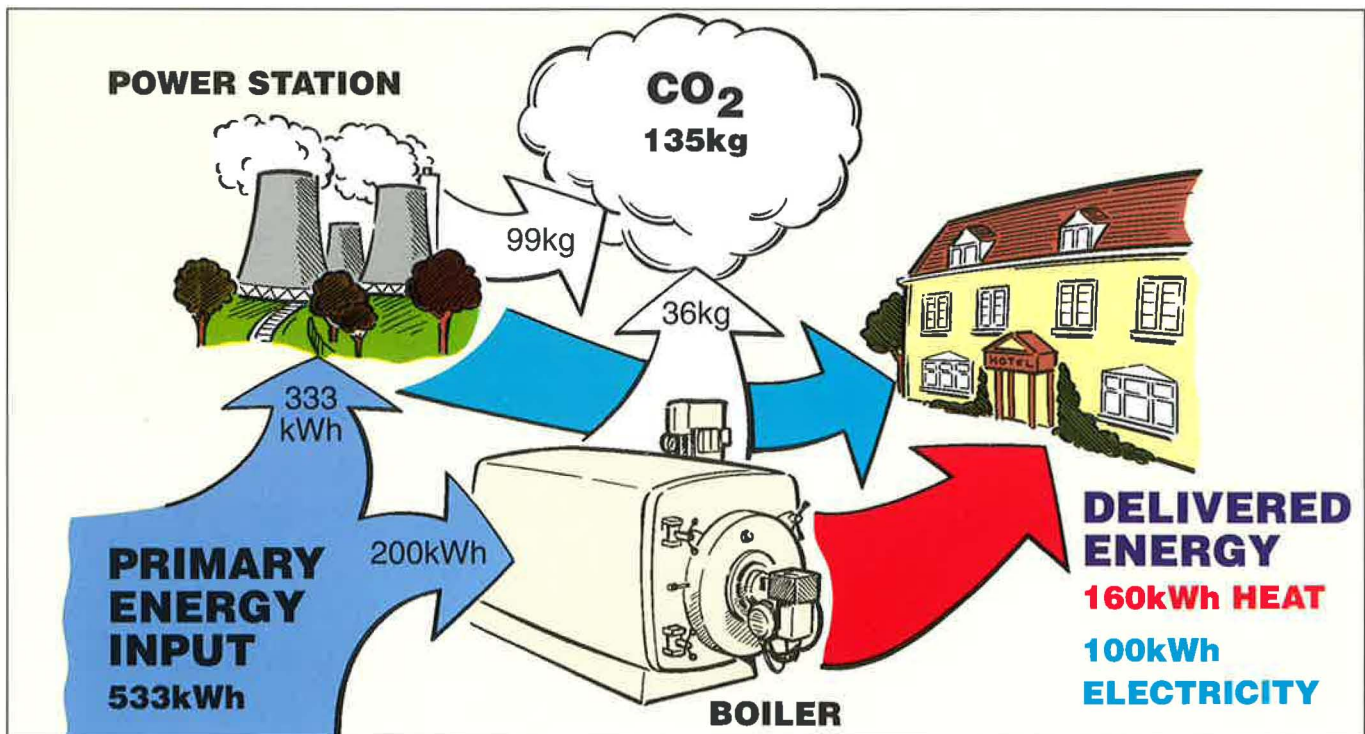
One particular type, the spark-ignition gas engine, has proved to be the best type of CHP plant for a range of building uses and sizes. Its basic operating principle is simple: the engine drives an alternator to generate electricity, and the heat from the exhaust and cooling systems is recovered for use in the building. Gas engines are available in a range of sizes. The electricity and heating demands of a building will dictate the size of unit installed. In short, your system will be tailored to suit your building's requirements.

### Improving Efficiency

CHP plant has already been proven as an efficient and cost-effective alternative for meeting a building's energy demand, but its environmental performance is equally impressive.

CHP is environment-friendly because it is more efficient at producing electricity and heat than conventional power stations and boiler plant. When a power station burns fuel to generate electricity, about 70% of the energy in the fuel is lost as waste heat. CHP is more efficient because it makes use of this waste heat by, for example, providing hot water.

By installing CHP, the total fuel consumed in on-site boilers and by power stations is effectively reduced. This in turn reduces the emissions of various gases into the air. To fully appreciate the benefit that CHP can have, it is necessary to consider the gases which result from burning fuel.



A power station and boiler providing electricity and heat



## Environmental Benefits from CHP

Installing CHP reduces emissions into the environment by reducing the total fuel consumed in on-site boilers and by power stations. On average, generating heat and electricity with a gas engine CHP unit results in primary energy savings of around 35%. For every unit of electricity provided by a gas engine, between 1.5 and 2.0 units of heat can be recovered to replace heat normally provided by boilers.

Table 1 shows the level by which a typical gas engine CHP plant affects the overall emissions of gases into the atmosphere.

The **60% reduction in CO<sub>2</sub>** emissions is a direct result of the more efficient use of fuel in CHP units; a 50 kW engine operating for 5,000 hours/year will give an annual reduction of over 190 tonnes of CO<sub>2</sub>.

This type of CHP unit results in higher NO<sub>x</sub> emissions; a 50 kW engine operating for 5,000 hours/year will give an annual increase of between 3 and 5 tonnes of NO<sub>x</sub>. However, by using the latest engines with catalytic converters there is **virtually no overall increase in NO<sub>x</sub> emissions.**

The effect on the overall emissions of CO is negligible, provided that effective combustion control is achieved.

If a gas engine CHP unit replaces electricity from a coal-fired power station, **emissions of SO<sub>2</sub> are reduced to zero.** Further savings in SO<sub>2</sub> are made if the CHP unit replaces oil- or coal-fired boiler

**Table 1 Emission reductions from gas engine CHP**

Emissions Sources	Emissions, in grammes/kWh of electricity supplied <i>Assumes CHP Heat to Power ratio of 1.6 : 1</i>			
	CO <sub>2</sub>	NO <sub>x</sub>	CO	SO <sub>2</sub>
Gas Engine CHP (1kWh electricity + 1.6kWh heat)	580	15 - 25	1 - 2	Negligible
Heat from Gas-Fired Boilers (1.6kWh)	360	0 - 1	0 - 1	Negligible
Electricity from Coal-Fired Power Stations (1kWh)	990	2 - 3	Negligible	15
Net change in emissions to atmosphere by switching to CHP	-770	11 - 23	0 - 2	-15

plant. A 50 kW engine operating for 5,000 hours/year will reduce SO<sub>2</sub> emissions by nearly 4 tonnes/year.

Overall, **CHP reduces the release of harmful emissions into the atmosphere.** All CHP plants reduce emissions of CO<sub>2</sub> and SO<sub>2</sub>. Gas engines can be fitted with catalytic converters that achieve much lower outputs of NO<sub>x</sub>, which eliminates the net increase in NO<sub>x</sub> emissions shown in Table 1.

### Legal Limits on Emissions from Small-scale CHP Plant

At present small-scale CHP in the UK is not subject to any limits on levels of emissions. The only constraints that apply are the general provisions of 'statutory nuisance' contained in the Environmental

Protection Act. These provisions do not hinder the use of a gas engine provided it is correctly installed and operated.

At present there are no plans to implement legislative limits in the UK for gas engine emissions. As a result the selection of engines has usually been based on meeting the heat and power needs of a building, while keeping the capital and operating costs as low as possible.

Some European countries apply limits on emissions of NO<sub>x</sub>, CO and UHC from gas engines. These limits generally require the use of catalytic converters to achieve them. This technology is proven and available, and its increased use within the UK is expected over the next few years. It can easily be fitted as an add-on to existing gas engines.



**Examples of buildings using small-scale CHP**



## Factors to be Considered When You Install a CHP System

CHP is usually installed in combination with boiler plant, so that both can supply heat to the building through the same system. The engine installation does not need any specific permit or authorisation, but if it involves a building extension you may need to obtain planning consent and building control approval from your local authority.

### CHP Exhaust

While the exhaust from an engine is not a source of danger to the local environment, it is important to make sure that the discharge is sited so that the exhaust gases are properly dispersed under all weather conditions. There must be no risk of the exhaust gases being drawn into air intakes or windows, and it is good practice to site the exhaust outlet above the eaves at an appropriate distance from any opening into the building. In addition, as the exhaust is relatively cool and contains water vapour, you must consider the problems of condensation in bad weather when siting the outlet.

### Noise

A CHP unit is relatively noisy when compared with other plant usually found in buildings, and you will need to consider potential noise problems at the design stage.

Some noise originates directly from the exhaust system and the engine. It is normal practice to fit the engine exhaust with a silencer, anti-vibration mountings and couplings, and for the equipment to be mounted on a single skid within an acoustic enclosure. Plant rooms are frequently fitted with additional sound-proofing, and putting the CHP system inside a solidly built structure will also help to reduce the noise heard outside. Noise is most likely to be a problem in residential areas or where occupied rooms are close to the plant room; in this case, you may need to take additional measures.

When designing the CHP layout, it may be necessary to take some noise measurements around the intended site to predict the effects that the gas engine will have on the area. Noise levels that cause a nuisance are subject to control under the Environmental Protection Act, and local authorities are obliged to investigate any complaints. Correct design of the CHP plant will ensure that no nuisance is caused to those inside and outside the building.

The experience gained to date with gas engine CHP covers a wide range of sites and locations. Correct engineering design can ensure that local environmental issues do not impede the installation of gas engine plants.

## New Developments Minimise Emissions

In a gas engine the amounts of  $\text{NO}_x$ , CO and UHC in the exhaust depend on the quantity of air mixed with the fuel in the engine. This characteristic has enabled special engine systems to be designed which use catalytic converters to reduce emissions.

One type of engine controls the air to fuel ratio very accurately, allowing a special catalytic converter to be used in the exhaust system. This is known as a '3-way catalyst' as it converts  $\text{NO}_x$ , CO and UHC into water,  $\text{CO}_2$  and nitrogen, giving a much cleaner and less harmful exhaust. The Case Study below identifies a development project that has achieved success with this type of engine system.

### Gas Engine Case Study

A development project was undertaken to produce an air/fuel ratio controller for use with gas engines. The system was designed to control the operating conditions of the engine with a 3-way catalytic converter in the engine exhaust.

A field trial has been carried out with the equipment fitted to an existing CHP gas engine. The trial took place over a continuous operating period of 2,500 hours, and the test results have confirmed that the system reduces  $\text{NO}_x$ , CO and UHC emissions by over 90%.

Another recent development is the 'lean burn' engine, which runs with a high air to fuel ratio. These engines produce up to 80% lower levels of  $\text{NO}_x$  than those shown in Table 1, but emissions of unburnt fuel and CO are increased slightly. An 'oxidation' catalyst can be used to convert these into  $\text{CO}_2$  and water.

The catalytic converters which allow these new engines to give cleaner exhausts and lower emissions have proved to be reliable, affordable and long-lived.



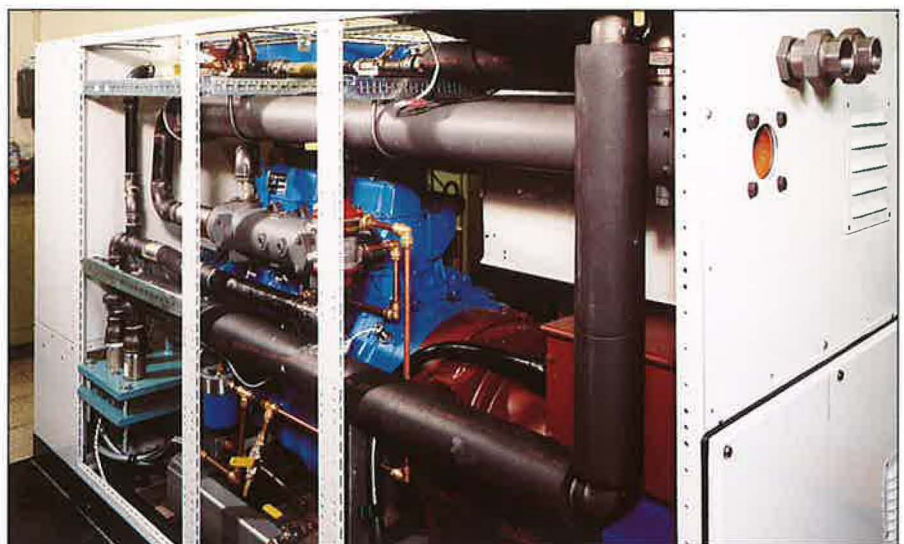
**A catalytic converter**

(Photograph courtesy of Johnson Matthey Catalytic Systems Division)

### Maintaining Efficiency

As with any plant, an engine installed as part of a CHP scheme must be properly maintained in order to keep it performing efficiently. If this is not done there can be losses in output together with increases in emissions of CO,  $\text{NO}_x$  and UHC. Suppliers can provide systems which monitor and control engines from remote sites via telephone links. This reduces the need for regular inspection and gives rapid diagnosis of faults.

Maintenance costs are an important factor when assessing a proposed CHP installation. Maintenance of an engine is a specialised function which is usually best carried out by an expert; most suppliers offer a service to maintain and repair gas engines in situ, including mobile engineers to respond to breakdowns. Proper attention to maintenance is vital to ensure that the CHP plant continues to provide the best energy efficiency, environmental and financial benefits possible.



**A packaged CHP unit with acoustic panels removed**



## The Culprits of Combustion

The burning of any hydrocarbon fuel results in exhaust gases which are damaging to the environment. The five culprits are:

- Carbon dioxide
- Carbon monoxide
- Sulphur dioxide
- Nitrogen oxides
- Unburnt hydrocarbons

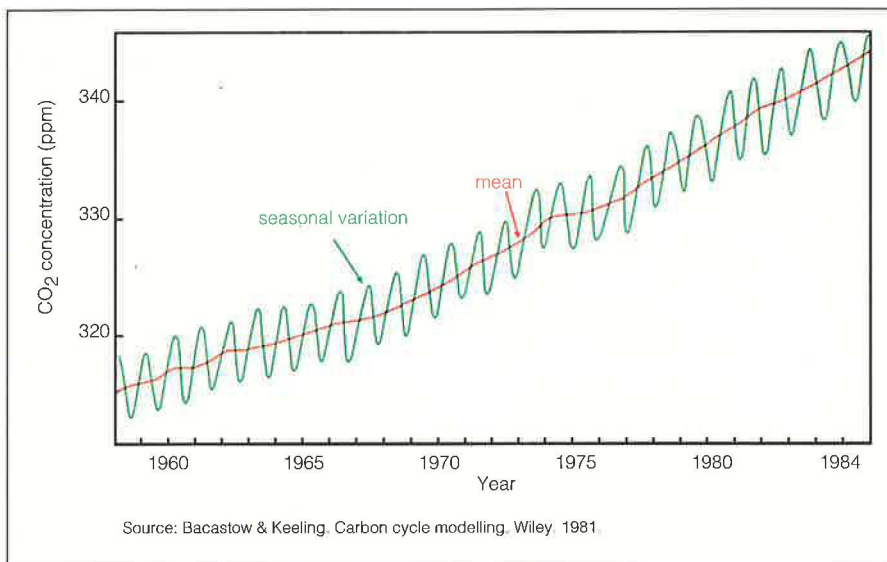
### Carbon Dioxide (CO<sub>2</sub>)

CO<sub>2</sub> is an important part of the natural and balanced carbon cycle of the Earth. However, CO<sub>2</sub> levels in the atmosphere are increasing due to human activities; this is a major cause of the greenhouse effect and the risks of global warming. The graph shows how CO<sub>2</sub> levels have increased over recent years. This is likely to continue if current fuel usage trends are not changed.

CO<sub>2</sub> is the exhaust gas produced in the greatest quantity by engines. For example, every tonne of natural gas that is burned gives off nearly 3 tonnes of CO<sub>2</sub>. However, because it uses fuels more efficiently CHP is an important means of reducing CO<sub>2</sub> emissions.

### Carbon Monoxide (CO)

CO is a poisonous gas which is produced when a carbon-based fuel is burned in insufficient air. If produced in large quantities it can contribute to the formation of local smog. However, if fuel and air levels are controlled correctly, emissions of CO can be kept at very low levels.



### The increase in CO<sub>2</sub> emissions

#### Sulphur Dioxide (SO<sub>2</sub>)

This gas is produced by burning any fuel that contains sulphur, and is a major cause of acid rain as well as causing corrosion damage to surfaces where condensation occurs. Nearly all small-scale CHP units run on natural gas which contains virtually no sulphur, and hence SO<sub>2</sub> emissions are negligible.

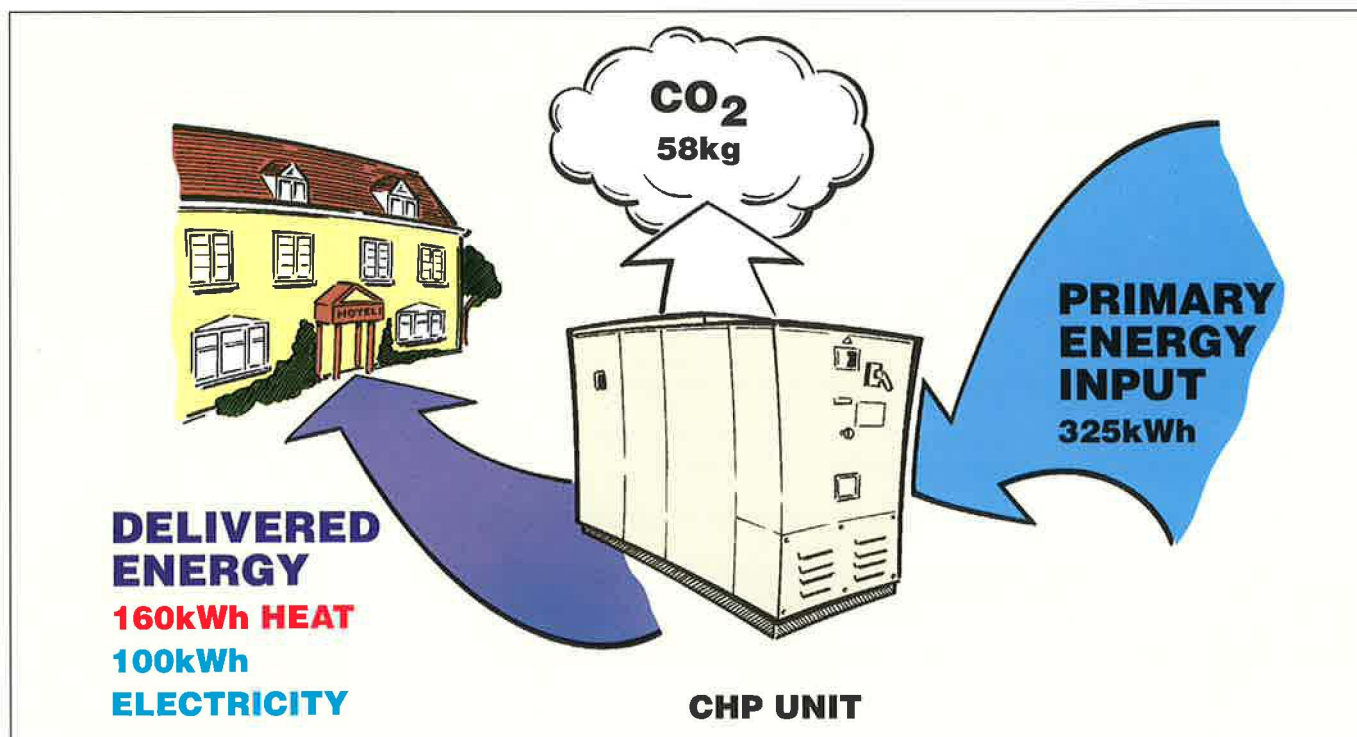
#### Nitrogen Oxides (known collectively as NO<sub>x</sub>)

These gases are produced by burning any fuel, but the amount created varies widely for a number of reasons. The amount of NO<sub>x</sub> formed in an engine is dependent on factors including combustion conditions, such as temperature and pressure, and the proportions of air and fuel present in the cylinder.

When NO<sub>x</sub> is released into the atmosphere it can be involved in various chemical reactions which result in ozone depletion and formation of smog. NO<sub>x</sub> also contributes to acid rain. Reductions in NO<sub>x</sub> emissions can therefore help to improve both the local and global environment.

#### Unburnt Hydrocarbons (UHC)

In the case of gas engines, small quantities of unburnt fuel can be found in the exhaust gases. This is often caused by poor control of air and fuel mixtures. The proportion of UHCs varies according to the engine design features. UHC emissions contribute to the greenhouse effect and to the formation of smog.



A small-scale CHP system providing electricity and heat

# CHP – The Environment-Friendly Option

Small-scale CHP has already proved itself as a highly beneficial technique for increasing energy efficiency and saving costs. Using CHP to replace heat from boilers and electricity from power stations also reduces emissions and therefore improves air quality.

The following list is a summary of the main points in this Guide. Could CHP be an environment-friendly option for your building?

## Summary

- Small-scale CHP achieves a 35% reduction in primary energy usage.
- Gas engine CHP achieves over 50% reductions in emissions of CO<sub>2</sub> and virtually eliminates emissions of SO<sub>2</sub>.
- Increases in overall NO<sub>x</sub> emissions occur with standard gas engines, but these can be eliminated by use of engine systems incorporating catalytic converters or by lean-burn engines.
- No further legislation on emissions from small-scale CHP is planned at present; if limits are imposed, they can be achieved by existing techniques.
- Any local environmental concerns can be overcome by good design and correct operation of the CHP plant.
- Planned maintenance of the engine by competent staff is essential to maintain the energy efficiency and environmental performance.

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